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(54) OPEN TRANSMISSION LINE INTRUSION DETECTION SYSTEM USING FREQUENCY SPECTRUM ANALYSIS

EINDRINGDETEKTIONSSYSTEM MIT OFFENER ÜBERTRAGUNGSLEITUNG MIT ANALYSE DES FREQUENZSPEKTRUMS

SYSTEME DE DETECTION D'INTRUSIONS A LIGNE DE TRANSMISSION OUVERTE, FAISANT APPEL A L'ANALYSE DU SPECTRE DES FREQUENCES

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- **PROCEEDINGS OF THE INTERNATIONAL CARNAHAN CONFERENCE ON SECURITY TECHNOLOGY, TAIPEI, OCT. 13 - 15, 1993, 13 October 1993, SANSON L D (ED), pages 139-142, XP000452687 HARMAN K ET AL: "SYNERGISTIC RADAR: RADIOGUARD APPLICATION AND PERFORMANCE"**
- **PROCEEDINGS OF THE ANNUAL INTERNATIONAL CARNAHAN CONFERENCE ON SECURITY TECHNOLOGY, ALBUQUERQUE, OCT. 12 - 14, 1994, no. CONF. 28, 12 October 1994, SANSON L D, pages 26-30, XP000492097 GAGNON A ET AL: "SYNERGISTIC RADAR: NOVEL APPLICATIONS AND PERFORMANCE"**

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Description

TECHNICAL FIELD:

[0001] The invention relates to intrusion detection systems and is especially applicable to systems which comprise an "open" transmission line, for example a so-called "leaky" or "ported" cable, for receiving a radio frequency signal and a receiver attached to the open transmission line for processing the received radio frequency signal to detect perturbations caused by an intruder in proximity to the open transmission line.

BACKGROUND ART:

[0002] Examples of such intrusion detection systems are disclosed in US patent number 3,163,861 (Suter) issued December 29, 1964, US patent number 3,794,992 (Gehman) issued February 26, 1974, US patent number 4,419,659 (Harman *et al*) issued December 6, 1983, US patent number 4,887,069 (Maki) issued December 12, 1989 and international patent application number PCT/CA93/00366 (Harman *et al*) published March 31, 1994. An intrusion detection system for an automobile, which uses several antennae and compares the spectrum of received television or radio signals with a predetermined pattern, is disclosed in German patent document No. DE 3,917,897 published December 1990.

[0003] To increase detection rates, the system disclosed by Gehman compares the signals from two adjacent cables, one via a quarter-wavelength section. Such duplication entails additional expense.

[0004] To avoid "null" problems which arise when an intruder crosses the line at a certain angular position, the system disclosed in international patent application number PCT/CA93/00366 uses two receivers, one at each end of the cable. The receivers are coupled to a reference antenna which receives a FM radio frequency signal directly from a nearby commercial radio transmitter and use synchronous detection to extract amplitude and phase modulation caused by the intruder and determine from them the presence of the intruder. At a fixed frequency, an intruder could cause a maximum amplitude modulation with minimum phase modulation or, conversely, maximum phase modulation with minimum amplitude modulation. Consequently, in order to maintain uniform detection along the line, the receivers use full vector demodulation of the in-phase (I) and quadrature (Q) components, where amplitude is $\sqrt{(I^2 + Q^2)}$ and phase is arc tg (Q/I).

[0005] The additional expense of such systems can be tolerated by "high end" users protecting very expensive property or high security areas such as military bases and correctional facilities. Such sites are likely to be serviced also by video surveillance systems or full time guards on site, so increased false alarm rates resulting from using sensors designed to give maximum probability of detection can be tolerated.

[0006] There is a need, however, for "low end" intrusion detection systems which are relatively inexpensive. For a particular site, system cost can be reduced by increasing the length of the open transmission line to limit the number of relatively expensive receivers and processors needed. A disadvantage of this approach, however, is that long sensor lines can increase the likelihood of undetected intrusion. Thus, attenuation along the length of the line may make it difficult to set the sensitivity so that the system will detect an intruder at the far end of the line while not being overloaded by perturbations caused by an intruder near to the receiver. Graded cables could be used to overcome this problem, but they are relatively expensive. Another disadvantage of long sensor lines concerns the need to allow legitimate access to a protected area such as a compound. When a sensor line across the entrance to a compound is switched off to allow a vehicle to enter, for example, the risk of an intruder gaining access at the same time is greater for longer sensor lines. Other problems which are exacerbated by longer sensor lines include variations in sensitivity caused by differing media along the length of the line; objects moving within the protected area; and increased range capability for any video monitors used in conjunction with the system.

DISCLOSURE OF INVENTION:

[0007] The present invention seeks to eliminate, or at least mitigate, one or more of the disadvantages of known intrusion detection systems and to provide an intrusion detection system which is relatively inexpensive yet reliable.

[0008] According to the present invention, an intrusion detection system comprises a plurality of sensors coupled to a corresponding plurality of receivers, each receiver having means (11-24) for receiving from the sensor coupled thereto a radio frequency signal having a multiplicity of transmissions at different frequencies within a predetermined frequency spectrum, the receiver being arranged to detect said multiplicity of transmissions and having computing means for periodically determining, for each of said multiplicity of transmissions, a corresponding signal amplitude measurement, comparing each signal amplitude measurement for each of the different frequencies with at least one preset threshold value and, if the amplitude exceeds the threshold value for a predetermined time period, indicating a potential alarm condition, the system further comprising means for monitoring the receivers for potential alarm conditions and signalling an actual alarm condition at least one of the receivers indicates potential alarm conditions for a predetermined number of different transmission frequencies within the same time period.

[0009] The receiver may include means for scanning an FM radio spectrum and selecting a number of said transmission frequencies, and computing means for sampling the amplitude of the FM radio signal received from the associated sensor over a predetermined time interval, each sample being said signal amplitude measurement, derive statistics of a plurality of said samples over each of successive time periods, and adjust the preset threshold value periodically in dependence upon said statistics.

[0010] The computing means may also derive higher and lower variance values of the amplitudes of the plurality of samples and use such variance values to determine respective upper and lower thresholds delimiting a range of acceptable amplitude values, and generate the potential intruder alarm signal when said measurement of signal amplitude is outside the range. The computing means then updates the threshold values periodically on the basis of mean and variance values computed for a predetermined number of samples.

[0011] Each sensor may comprise an open transmission line, the open transmission lines being concatenated by the plurality of receivers, a first of the receivers being connected to the common processor for processing signals from the different receivers, each of the receivers other than the first receiver interconnecting two of the open transmission lines, each receiver being arranged to transmit station alarm signals to the common processor by way of any intervening open transmission lines and receivers.

[0012] The common processor may supply power to the receivers by way of intervening transmission line(s) and/or receivers.

[0013] One or more of the sensors may comprise a localized antenna acting as a single point in space instead of a distributed antenna in the form of an open transmission line.

[0014] The intrusion detection system may comprise a plurality of sub-systems sharing the common processor, the sub-systems being physically separated from each other. The sub-systems and the common processor may then have respective transceivers for communicating station alarm signals and control signals between each sub-system and the common processor.

[0015] Various objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description, taken in conjunction with the accompanying drawings of preferred embodiments of the invention, which are described by way of example only.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0016]

Figure 1 is a schematic conceptual diagram of an intrusion detection system of a first embodiment of the invention comprising several open transmission line sensors and associated receivers;
Figure 2 is a schematic block diagram of one of the receivers;
Figure 3 is a statistical distribution of amplitude levels for an FM radio signal received by one of the receivers;
Figure 4 is a flowchart depicting operation of one of the receivers;
Figure 5 is a flowchart depicting operation of a common processor of the system;
Figure 6 is a block schematic diagram of a second embodiment of the invention;
Figure 7 is a block schematic diagram of a third embodiment of the invention:
Figure 8 is a block schematic diagram of a fourth embodiment of the invention:
Figure 9 is a block schematic diagram of a fifth embodiment of the invention:
Figure 10 is block schematic diagram of a sixth embodiment of the invention:
Figure 11 illustrates in more detail a receiver of the system of Figure 10: and
Figure 12 illustrates a modification of the system of Figure 10.

BEST MODES FOR CARRYING OUT THE INVENTION:

[0017] Referring first to Figure 1, an intrusion detection system comprises a series of similar open transmission lines in the form of so-called "leaky" or "ported" cables designated **2A, 2B, 2C...2N...2X** and receivers, designated **3A, 3B, 3C....3N...3X,** connected in series between a common processor **4** and a termination load **5** to form, in effect, a linear bus defining a corresponding series of protection zones **A** to **X.** The cables **2A...2X** serve as sensors. The common processor **4** is connected to the first receiver **3A** by a feedline **6** and connected to a DC power supply by line **7.** The common processor **4** relays DC power to the receivers **3** by way of the feedline **6** and cable or cables **2.** The final cable **2X** is connected at one end to the termination load **5** and at the other end to receiver **3X.** A separate transmitter **8** broadcasts FM radio signals which are received by the cables **2A...2X.** Preferably, the transmitter **8** is a commercial FM radio station transmitter broadcasting a multiplicity of radio station transmissions having different frequencies within a predetermined frequency spectrum, typically 88 MHz. to 108 MHz. The transmitter could, however, be a part of the intrusion detection system and transmit a multiplicity of signals within a similar frequency spectrum. In this case, however, the transmissions would be unlikely to have FM modulation, as opposed to commercial radio station transmissions.

[0018] Each of the receivers **3A...3X** receives the radio frequency signal picked up by the associated one of cables **2A...2X** and scans the frequency spectrum; measures and digitizes the amplitude of each FM station detected; and processes the amplitude measurement of each station to determine a potential Station Alarm condition. If such a condition occurs in zone **N,** the receiver **3N** transmits a "Station Alarm", via the intervening cable or cables (if applicable) and feedline **6** to the common processor **4** which determines correlation between Station Alarms of adjacent detection zones **N+1** and **N-1** to determine whether or not to output a "System Alarm on Zone **N"** signal on line **9.**

[0019] The receivers **3A** to **3X** are identical so the construction and operation of only one of them, receiver **3N,** will now be described. Referring to Figure 2, in receiver **3N,** the radio frequency signal received from the associated sensor cable **2N** is coupled to the common connection of a capacitor **11** and inductor **12** of a bias-T circuit **13.** The capacitor **11** couples the radio signal to a bandpass filter **14** which restricts the radio signal to the FM spectrum from 88 MHz. to 108 MHz. and passes it to a low noise amplifier **15.** The amplified signal from amplifier **15** is down-converted to an intermediate frequency (IF) signal of 10.7 MHz. by a mixer **16** which derives its local oscillator signal (LO) from a phase-locked loop oscillator (PLO) **17.** The PLO **17** is controlled, via bus **18,** by a microcontroller **19** which causes the local oscillator frequency to scan the spectrum and detects the transmissions from up to ten FM radio stations.

[0020] For each transmission frequency, the down-converted IF signal from mixer **16** is filtered by a second bandpass filter **20** having a bandwidth of 300 kHz. centered upon the IF frequency. The magnitude of the output from second bandpass filter **20** is measured using a logarithmic amplifier **21.** The analog signal from the logarithmic amplifier **21** represents the amplitude of the radio frequency signal for a selected station and is filtered by a low pass filter **22** having a cut-off of 80 Hz. The filtered signal **Ar,N** from low pass filter **22** is converted to an eight bit digital signal by analog-to-digital (A-to-D) converter **23** within the microcontroller **19.** The digital signal from A-to-D converter **23** is processed by a signal processor **24** of the microcontroller **19,** as will be described in more detail later. If it determines that an intruder may be present in zone N, i.e. a potential alarm condition, the signal processor **24** generates a "Station Alarm" signal for the particular station and supplies it by way of line **25** and a series inductor **26** of a second bias-T **27** onto the preceding cable **2N-1** for transmission to the common processor **4** via the receiver **3N-1** and the preceding receivers and cables. The signal processor **24** will add an address and time stamp for receiver **3N** to the "Station Alarm" signal and, depending upon the network topology of the various receivers and cables, incorporate a network communication protocol.

[0021] D.C. power for the receivers **3A...3X** is transmitted from the common processor **4** via the cables **2A...2X** and feedline **6.** As shown in Figure 2, a 5 volt regulator **28** connected to inductor **26** of bias-T circuit **27** receives the D.C. power supply signal from cable **2N-1.** The regulator **28** supplies a regulated voltage on line **29** to the various components of the receiver **3N** and relays power supply signal via the inductor **12** of bias-T circuit **13** for coupling to the cable **2N** for supply to the succeeding receivers.

[0022] The shunt arm of second bias-T circuit **27** comprises, in series with the usual capacitor **30,** a **75** ohm resistor **31** to terminate the cable **2N-1** properly to ground.

[0023] The receiver **3N** may also receive via cable **2N** "Station Alarm" signals generated by receiver **3N+ 1** itself or generated by succeeding receivers up to **3X** and relayed via receiver **3N+1.** These signals are digital signals modulated onto a carrier of, for example, about 4 kilohertz. Being relatively low frequency, they are coupled by the inductor **12** of bias-T circuit **13** to input port **32** of the signal processor **24,** which will combine them with its own "Station Alarm" signal, if any, for transmission to the common processor **4** via its communication line 25.

[0024] Upon receipt of a "Station Alarm" from any one of the receivers **3,** the common processor **4** will compare the Station Alarm signals for adjacent zones. In the linear bus arrangement of Figure 1, this will entail comparing with the signals from the immediately preceding and succeeding receivers, but other network tropologies, to be described later, may entail different comparisons. In essence, the signals from the other receivers serve as the reference for the receiver generating the "Station Alarm". Hence, unlike the system disclosed in international patent application number PCT/CA93/00366, there is no need for a separate reference antenna to receive the radio frequency signal direct from the transmitter antenna **8.** In this case, each neighbouring zone serves as the reference antenna for the "center zone". Also, whereas the detection process described in PCT/CA93/00366 is coherent, the present detection technique is non-coherent, i.e. comparison does not involve synchronous detection of amplitude and phase but rather entails a form of frequency spectrum analysis (asynchronous detection of amplitude) particular to each zone.

[0025] The manner in which the system determines whether or not an intruder is present in zone **N,** i.e. surrounding cable **2N,** will now be described with reference also to Figure 3 and the flowchart of Figure **4.** In step **33,** the microcontroller **19** adjusts the oscillator **17** to cause the receiver **3N** to scan the frequency spectrum and register the ten stations having the strongest signals for zone **N.** In steps **34** and **35,** the signal processor **24** selects the transmission frequency for station i and measures the amplitude $\mathbf{A_r}$**.** The processor **24** filters the amplitude measurement using digital filtering techniques (not shown) to avoid false alarms caused by drift. The processor **24** then samples the filtered measurements $\mathbf{A_f}$ as previously described and records the amplitudes of the samples. The receiver measures the amplitude $\mathbf{A_f}$ of the signal over a period of about five minutes, sampling the signal at a rate of, say, 500 samples per second. The actual number of samples or sampling window will depend upon the particular application, taking account of factors such as environment, temperature drift, and so on. The resulting histogram is shown in Figure 3 which plots the number of occurrences, in a moving window of, in this example, five minutes, against the filtered amplitude A_f of a particular FM station **M.** Statistical values are recorded are as follows:

A_f -	filtered amplitude of the FM station **M**
$\tilde{X}$ -	statistical mean (first order moment or center of gravity)
σ^2_H -	variance for the high side (second order moment)
σ^2_L -	variance for the low side (second order moment)
T_H -	threshold for the high side
T_L -	threshold for the low side

[0026] In steps **36** and **37**, the receiver determines whether or not the instant sample of the filtered amplitude signal $\mathbf{A_f}$ is outside the range delimited by the upper threshold $\mathbf{T_H}$ and the lower threshold $\mathbf{T_L}$ for more than **X** counts, say 5 - 50 consecutively. The actual number of counts may be chosen to avoid responding to transient phenomena. If neither threshold has been traversed, in steps **38** and **39** the processor **24** updates for that particular station the mean value $\tilde{X}$, and variance values σ^2_H and σ^2_L which it computes using the samples taken during the previous five minutes (15,000 samples for each of the ten stations). It then determines the lower and higher threshold values $\mathbf{T_L}$ and $\mathbf{T_H}$ according to the expressions:-

$$T_H = \tilde{X} + T\,\sigma_H^2$$

and

$$T_L = \tilde{X} - T\,\sigma_L^2$$

where T is a multiplier set by the user to determine sensitivity for zone **N.**

[0027] Had the histogram been symmetrical, the values could have been rectified and compared with a single threshold. In practice, however, it is skewed so lower and upper thresholds T_L and T_H are used. An intruder will cause the histogram to shift along the 'amplitude' axis quite quickly. Drift due to, for example, weather conditions is relatively slow, so false alarms due to drift are avoided by allowing the mean $\tilde{X}$ to follow the drift, which occurs because the mean is updated at sample speed, being recalculated for every new sample and thus for each FM station individually for each zone **N.**

[0028] If, in step **36** and **37,** the signal processor **24** determines that the threshold has been exceeded for the specified count, in step **40** it sets a flag for the instant station in the "Station Alarm" mode. The conditions of the signal from the instant station **i** for which the receiver will signal a Station Alarm condition are:

Alarm	$S_i = 1$, if $A_f \langle T_L$ or $A_f \rangle T_H$ for more than a count of **X**
No alarm	$S_i = 0$ otherwise

[0029] In step **41**, the processor **24** determines whether or not signals for all ten stations have been processed. If not, step **42** increments the station counter and loop **43** returns the program to step **34** to select the next station. The various values determined by the processor **24** in each cycle are tabulated in Tables I and II.

STATION M	A_f
1	
2	
3	
" " "	
10	

TABLE I

⇒

M	LAST BLOCK OF SAMPLES newest				oldest
	1	2	3	...	15,000
1					
2					
3				...	
" " "					
10					

TABLE II

[0030] A sampling rate of 500 samples per second allows 50 samples for each of the ten stations. Hence, the moving sampling window of 5 minutes will accommodate 15,000 samples for each station.

[0031] When all ten stations have been processed, step **44** determines whether or not any of the stations are in the "Station Alarm" mode. If none are, step **45** resets the station counter to "**1**" and loop **46** returns the program to step **34** to repeat the cycle. The processor **24** records the statistical values for the ten stations as shown in Table III below:

M	$\tilde{X}$	σ_L^2	σ_H^2	T_L	T_H	STEP DETECT	ALARM COUNT	STATION ALARM
1	"	"	"	"	"	(1,0)	c	(1,0)
2	"	"	"	"	"	"	"	"
3	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
10	"	"	"	"	"	"	"	"

TABLE III

[0032] The values $\tilde{X}$, σ^2_H, σ^2_L, T_L, T_H are recorded together with an indication of whether or not a step change in the amplitude of the station's transmission has been detected, indicated by a "1" in the STEP DETECT column, the number of potential alarm conditions counted and, finally, the Station Alarm condition for each station, as a "1" or "0".

The alarm count required to register a Station Alarm will be determined by the user for every zone according to the particular application. For example, if the sensor is along a rooftop, an intruder will be moving quite slowly the alarm count will be high, say 50 counts, which is the equivalent of 1 second at the rate of 50 samples per second. Where the sensor is in an open area, and the intruder could be moving quite quickly, the count could be lower, say 10 or fewer.

[0033] If step **44** indicates that one or more of the stations are in "Station Alarm" mode, step **47** assembles a Station Alarm packet as illustrated below for transmission of the alarm conditions for the different station **M** to the common processor **4.**

Header	Zone Address	Time	Status	Station Alarm	CRC	Tail
5 bit	8 bit	16 bit	3 bit	10 bit	3 bit	5 bit

[0034] The packet comprises, in succession, a header of five bits; a zone address of eight bits to identify the sensor zone for which the receiver is reporting; a time slot of 16 bits to correlate the Station Alarm temporally with those of adjacent zones; with three status bits giving an indication of conditions at the receiver, such as failure, jamming, interference, and so on; ten bits representing the alarm conditions for the ten stations; three correction bits; and finally a five bit ending or tail.

[0035] Operation of the common processor **4** upon receipt of the packets from the various receivers will now be described with reference also to the flowchart in Figure 5. Whereas the receiver 3 scans the sensors repeatedly and continuously as described above, the common processor operates on an "interrupt" basis. Thus, in step **48,** the common processor **4** is in a WAIT state awaiting a packet containing one or more Station Alarms. On receipt of such a packet in step **49,** for zone **N,** the common processor **4** extracts from the packet the Station Alarm information and records it with the information for the other sensor zones **A...X,** mainly for **N-1** and **N+1** as represented by the matrix $S_{M,N}$ shown below in Table IV.

Table IV

Zone	Status of Station **M** Alarm at Time **t**									
	1	2	3	4	5	6	7	8	9	10
A	(1,0)	.	.	.	.	.	.	.	.	.
B	.	.	.	.	.	.	.	.	.	.
C	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	..	.	.	.	.
.	.	.	.	.	($S_{M,N}$)	.	.	.	.	.
N-1	.	.	.	.	.	.	.	.	.	.
N	.	.	.	.	.	.	.	.	.	.
N+1	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
X	.	.	.	.	.	.	.	.	.	.

[0036] It is possible for the amplitude of the received signal to vary sufficiently to generate a Station Alarm without there being an intruder present, perhaps caused by a change at the transmitter or a change in weather conditions. In order to avoid such false alarms, in step **50** the common processor **4** detects a Station Alarm condition for a particular station **i** in the Station Alarm status bits for zone **N** and checks the alarm status of the same station **i** for the adjacent zones **N-1** and **N+1**. Decision step **51** determines whether or not the station alarm for a particular station **i** is reported for the particular zone **N** alone. If it is not, i.e. an adjacent zone simultaneously shows a Station Alarm for the same station **i,** the condition is likely to be a false alarm, perhaps caused by a sudden change in the signal level at the transmitter **8** or a remote disturbance affecting many zones simultaneously, so the program goes to step **55** and resets the station alarm flag to the "NO ALARM" state, following which the program returns to step **48** and awaits receipt of another packet containing a Station Alarm.

[0037] If, however, step **51** determines that neither of the adjacent zones shows a simultaneous alarm for station **i,** step **52** sets a Station Alarm flag for station **i** and zone **N**. Thus:

If

$S_{M,N} = 1$
$S_{M,N-1} = 0$
$S_{M,N+1} = 0$

[0038] Then Zone **N** Station Alarm = 1,
where **M** is the number of stations to a maximum of 10.

[0039] In step **53,** the processor **4** determines whether or not more than 50 per cent of the station alarms for zone **N** are showing an alarm condition simultaneously. If they are not, the program returns to step **51** and processor **4** does not generate a SYSTEM INTRUDER ALARM signal for zone **N.** If step **52** indicates that more than 50 per cent of the station alarms for zone **N** indicate an alarm condition, step **54** generates a SYSTEM INTRUDER ALARM signal for zone **N** indicating that an intruder has been detected within zone **N.**

[0040] Various modifications can be made to the above-described embodiment within the scope of the present invention. Thus, the processor **24** may be preprogrammed with sets of values of sensitivity **T,** consecutive count **X,** and so on per zone **N** for each of a number of typical applications. When setting up the system, the user may select one of the applications. The individual values may then be adjusted to take account of data collected during operation of the system. The adjustment may be effected by sending control signals to the microcontrollers via the cables.

[0041] Although the linear bus configuration of Figure 1 is preferred, since the number of receivers and sensor cables is, theoretically, unlimited, the invention embraces other configurations. The embodiment shown in Figure **6** comprises only two sensor cables **2A** and **2B** connected to receivers **3A** and **3B,** respectively and each terminated by a termination load **5.** The receivers **3A** and **3B** are connected to a common processor **4** by feedlines **6A** and **6B,** respectively, which supply DC power and control signals to the receivers and return Station Alarm signals to the common processor **4.** The receivers **3A** and **3B** may be similar to those illustrated in Figure 2 but, since this embodiment does not concatenate cables, need not have provision for relaying DC power to subsequent receivers and their Station Alarm signals back to the common processor **4.**

[0042] Various other modifications are envisaged. Thus, Figure **7** illustrates an embodiment in which, with the object of minimizing cost, a receiver **3** is combined with a common processor **4** and connected to a pair of sensor cables **2A** and **2B** via a multiplexer **57.** The common processor **4** controls the multiplexer **57** to couple the cables **2A** and **2B** alternately to the receiver **3**. The common processor **4** discriminates between the Station Alarms for the two cables/zones and outputs corresponding alarm signals for zones **A** and **B.**

[0043] It is also envisaged that the intrusion detection systems of Figures 6 and 7 could have one or more of the leaky cable sensors replaced by a localized antenna connected directly to the common processor **4.** The antenna will serve as a single-point-in-space sensor to detect presence of an intruder. The common processor **4** will process signals from both the leaky cable(s) and the antenna in much the same way.

[0044] The embodiment illustrated in Figure **8** comprises receivers **3** and three-port receivers **3'** connected to leaky cables in an arbitrary network topography. Receivers **3** are similar to those in Figure 1 and connect single sensor cables in a bus configuration, as in the embodiment of Figure 1. Three-port receivers **3'** connect three cables together at a T-junction. The three-port receivers **3'** may be duplicate circuitry to accommodate the additional port, or use multiplexing. The first receiver **3A** is connected to the common processor **4** by a feedline **6** as before. As before, the common processor **4** supplies DC power to the receivers via the intervening sensor cables and feedlines and receives their Station Alarm signals via the same route.

[0045] The system illustrated in Figure **9** comprises **M** physically separate sensor sub-systems **S1, S2... SM,** of which only three are shown, protecting distinct areas. Sub-system **S1** comprises a single cable **2A** connected at one end to a receiver **3A** and at its other end to a termination load **5.** Sub-system **S2** comprises two cables **2X** and **2Y** each connected to a respective termination load **5** and to respective ports of a receiver **3XY.**

[0046] Third sub-system **SM** comprises a linear arrangement of two cables **2I** and **2J** connected to receivers **3I** and **3J** respectively. Cable **2J** is terminated by a termination load **5.** Receiver **3I** has a DC power supply and supplies power to receiver **3J** via cable **2I.** As in the embodiment of Figure 1, Station Alarm signals from receiver **3J** are relayed to receiver **3I** via cable **2I.**

[0047] As before, the sub-systems **S1, S2 ... SM** use FM radio signals broadcast from a remote, independent commercial transmitter (not shown in Figure 7) to detect intruders and use wireless transceivers to communicate their respective Station Alarms to common processor **4.** In this case, however, the receivers **3** and the common processor **4** each have a transceiver section coupled to an antenna **56** enabling the common processor **4** to transmit control signals to the receivers and receive their Station Alarm signals.

[0048] Figure 10 illustrates yet another embodiment of the invention comprising a common processor **4** and a series of receivers **3A"-3I"** interconnected by a series of feedlines **6A- 6I** instead of leaky cables. The feedlines **6** may conveniently be standard twisted pair shielded cable. The receivers are connected to respective FM antennas **58** and form a linear bus arrangement similar to that of Figure 1. Each FM antenna **58** receives FM signals broadcast by a remote commercial radio transmitter (not shown) and the receiver processes the signal statistically in the manner previously described to determine the presence of an intruder affecting the signal received by the associated antenna. As shown in Figure **11,** each of the receivers **3A"** to **3I"** has a bias-T circuit **59** at its input port. A serial inductor **60** of the bias-T circuit is connected to the feedline **6** and the branch capacitor **61** of the bias-T circuit is connected to the antenna **58,** enabling DC power and control signals to be relayed via the feedlines **6** to the receivers **3A"** to **3I"** and their Station Alarm signals to be returned to the common processor **4** via the same path. The antennas **58** perform localized volume detection as opposed to perimeter detection.

[0049] As illustrated in Figure **12,** such a FM receiver **3"** and antenna **58** (in this case a loop antenna) could be mounted directly upon an article **62** to be protected to detect any motion of the article **62** itself in addition to motion of someone approaching it. The receiver **3"** has a DC input terminal **63** and an antenna **58** distributed around the article **62** which serves as both a sensor to receive the FM broadcast and control signals and a transmitting antenna for communicating Station Alarm signals to the common processor **4,** which has an antenna **64** for receiving Station Alarm signals and transmitting control signals to the receiver **3".**

[0050] Advantageously, in any of the above-described embodiments of the invention, one or more cameras may be associated with one or more of the sensor zones to provide video surveillance in combination with the intrusion detection by leaky cables, enabling false alarms to be determined by the video surveillance systems. With such an arrangement, the detection sensitivity may be increased as compared with a stand-alone system.

[0051] It should be appreciated that, although the above-described embodiments use FM transmissions in the usual broadcast bands of 88 MHz. to 108 MHz., they could use any "man made" electromagnetic signal, for example the cellular telephone frequency in the 900 MHz. band.

[0052] It should also be appreciated that the different transmissions could emanate from different transmitters rather than the single transmitter **8** of the preferred embodiment described herein. Moreover, the system is not limited to ten station frequencies as described herein but could use practically any number.

[0053] An advantage of embodiments of the present invention which use an array or network of modules, each module comprising a segment of open transmission line and a receiver, is improved flexibility. Thus, for a particular perimeter to be protected, the user can employ different modules with different sensitivities to suit local conditions or differing media along the perimeter, such as when the line runs along the roof and sides of a building and their construction differs. Also, modular construction allows the system to be easily extended and/or adapted to take account of changes to the site, such as new construction; or readily reconfigured when moved to a new site. Individual modules can have their sensitivities adjusted or even be turned off entirely at certain times. The modular system is also less vulnerable to damage or complete shut-down.

[0054] An advantage of embodiments of the invention using a form of frequencies spectrum analysis of received signals is that the receivers are inexpensive as compared with those used in systems which use network analysis techniques to process and analyze the received signals and extract in-phase (I) and quadrature (Q) components of the modulation caused by the intruder, which involves greater complexity and cost.

[0055] An advantage of embodiments of the invention having several receivers with adjustable detection thresholds T_L/T_H and successive counts **X** is that the user can select different detection sensitivities for the different zones simply by presetting different values of multiplier **T** and count **X** for different receivers. Also, higher sensitivity can be used for zones which are also monitored by cameras, in which case a greater number of false alarms from the intrusion detection system can be tolerated.

[0056] Although embodiments of the invention have been described and illustrated in detail, it is to be clearly understood that the same are by way of illustration and example only and not to be taken by way of the limitation, the scope of the present invention being limited only by the appended claims.

INDUSTRIAL APPLICABILITY

[0057] Embodiments of the invention may be used to monitor military, commercial or residential property for unauthorized entry by intruders.

Claims

1. An intrusion detection system **characterized by** a plurality of sensors (**2A...2X**) coupled to a corresponding plurality of receivers (**3A...3X**), each receiver having means (11-24) for receiving from the sensor coupled thereto a radio frequency signal having a multiplicity of transmissions at different frequencies within a predetermined frequency spectrum, the receiver being arranged to detect said multiplicity of transmissions and having computing means (**24**) for periodically determining, for each of said multiplicity of transmissions, a corresponding signal amplitude

measurement, comparing each signal amplitude measurement for each of the different frequencies with at least one preset threshold value and, if the amplitude exceeds the threshold value for a predetermined time period, indicating a potential alarm condition, the system further comprising means (4) for monitoring the receivers for potential alarm conditions and signalling an actual alarm condition when at least one of the receivers indicates potential alarm conditions for a predetermined number of different transmission frequencies within the same time period.

2. An intrusion detection system as claimed in claim 1, **characterized in that** each receiver includes means (**17,18,19**) for scanning an FM radio spectrum and selecting a number of said transmission frequencies, and the computing means (**24**) is arranged to sample the amplitude of the FM radio signal received from the associated sensor over a predetermined time interval, each sample being said signal amplitude measurement, derive statistics of a plurality of said samples over each of successive time periods, and adjust the preset threshold value periodically in dependence upon said statistics.

3. An intrusion detection system as claimed in claim 2, **characterized in that** the computing means (**24**) is arranged to compare each signal amplitude measurement with an upper preset threshold value and a lower preset threshold value, determine higher and lower variance values of the plurality of amplitude samples update the upper and lower thresholds in dependence upon the upper and lower variance, respectively, and indicate said potential alarm condition when a predetermined number of said amplitude samples are outside a range defined by the upper and lower thresholds.

4. An intrusion detection system as claimed in claim 1, **characterized in that** the monitoring means (4) comprises a processor unit having means for receiving data about said potential alarm conditions from said receivers (**3A...3X**), the receivers each having means (24,25,26) for transmitting said data to the processor unit (4), the processor unit being arranged to signal said actual alarm condition when potential alarm conditions from a particular receiver occur for at least a predetermined proportion of said multiplicity of transmissions in a predetermined time interval.

5. An intrusion detection system as claimed in claim 1, **characterized in that** the monitoring means comprises a common processor (**4**) for comparing potential alarm condition states for a particular sensor with corresponding potential alarm condition states of at least one immediately neighbouring sensor and determining an intrusion to have occurred if the potential alarm condition for said particular station does not coincide with an alarm signal for said at least one immediately neighbouring sensor.

6. An intrusion detection system as claimed in claim 5, **characterized in that** each sensor (**3A...3X**) comprises an open transmission line, a first receiver (**3A**) being connected to the common processor (**4**) for processing signals from the different receivers, each of the subsequent receivers **(3B...3X)** interconnecting two of the open transmission lines, each receiver being arranged to relay potential intruder alarms signal from later receivers to the common processor by way of any intervening open transmission lines and receivers.

7. An intrusion detection system as claimed in claim 6, **characterized in that** the common processor (**4**) is arranged to supply power to the receivers by way of the intervening transmission line.

8. An intrusion detection system as claimed in claim 1, **characterized in that** at least one of the sensors comprises a localized antenna (**58**).

9. An intrusion detection system as claimed in claim 1, **characterized in that** the receivers are arranged in a plurality of sub-systems (**S1...SM**) each comprising at least one of the receivers, and wherein the monitoring means comprises a common processor (4), the sub-systems being physically separated from each other, the sub-systems and the common processor having respective transceivers for communicating alarm signals from each sub-system to the common processor.

10. An intrusion detection system as claimed in claim 1, **characterized in that** said predetermined frequency spectrum is from about 88 MHz. to 108 MHz.

Patentansprüche

1. Eindringdetektionssystem **gekennzeichnet durch** eine Mehrzahl von Sensoren (2A...2X), die an eine entspre-

chenden Mehrzahl von Empfängern (3A...3X) gekoppelt sind, wobei jeder Empfänger Mittel (11-24) zum Empfangen eines Hochfrequenzsignals von dem daran angeschlossenem Sensor aufweist, mit einer Vielzahl von Übertragungen bei unterschiedlichen Frequenzen innerhalb eines vorbestimmten Frequenzspektrums, wobei der Empfänger zum Erfassen der Vielzahl von Übertragungen angeordnet ist, und eine Rechneranordnung (24) aufweist zum periodischen Erfassen einer entsprechenden Signalamplitudenmessung für jede der Vielzahl von Übertragungen, zum Vergleichen jeder Signalamplitudenmessung für jede der verschiedenen Frequenzen mit zumindest einem vorgegebenen Schwellenwert, und zum Anzeigen eines potentiellen Alarmzustands, wenn die Amplitude den Schwellenwert über eine vorbestimmte Zeitdauer überschreitet, wobei das System weiterhin Mittel (4) zum Überwachen der Empfänger für potentielle Alarmzustände und zum Melden eines tatsächlichen Alarmzustands umfasst, wenn zumindest einer der Empfänger potentielle Alarmzustände für eine vorbestimmte Anzahl von verschiedenen Übertragungsfrequenzen innerhalb der gleichen Zeitdauer anzeigt.

2. Eindringdetektionssystem nach Anspruch 1, **dadurch gekennzeichnet, dass** jeder Empfänger Mittel (17, 18, 19) zum Abtasten eines FM Hochfrequenzspektrums und zum Auswählen einer Anzahl der Übertragungsfrequenzen umfasst, und dass die Rechneranordnung (24) angeordnet ist, die Amplitude des von dem zugeordneten Sensor empfangenen FM Hochfrequenzsignals über eine vorbestimmte Zeitdauer in Abschnitte zu zerlegen, wobei jeder Abschnitt eine Signalamplitudenmessung ist, Statistiken der Vielzahl dieser Abschnitte über jede der aufeinanderfolgenden Zeitabschnitte abzuleiten, und den voreingestellten Schwellenwert in Abhängigkeit von diesen Statistiken periodisch einzustellen.

3. Eindringdetektionssystem nach Anspruch 2, **dadurch gekennzeichnet, dass** die Rechenanordnung (24) angeordnet ist, jedes Signalamplitudenmessung mit einem oberen voreingestellten Schwellenwert und einem unteren voreingestellten Schwellenwert zu vergleichen, höhere und niedrigere Abweichungswerte der Vielzahl von Amplitudenabschnitten zu erfassen, die oberen und unteren Grenzen in Abhängigkeit von der oberen beziehungsweise unteren Abweichung zu aktualisieren, und den potentiellen Alarmzustand anzuzeigen, wenn eine vorbestimmte Anzahl der Amplitudenabschnitte außerhalb eines von der oberen und unteren Schwelle begrenzten Bereichs liegen.

4. Eindringdetektionssystem nach Anspruch 1, **dadurch gekennzeichnet, dass** die Überwachungseinrichtung (4) eine Prozessoreinheit umfasst, welche Mittel zum Empfangen von Daten über die potentiellen Alarmzustände von den Empfängern (3A....3X) aufweist, wobei die Empfänger jeweils Mittel (24, 25, 26) zum Übertragen der Daten an die Prozessoreinheit (4) aufweisen, dass die Prozessoreinheit angeordnet ist, den tatsächlichen Alarmzustand zu melden, wenn potentielle Alarmzustände von einem bestimmtem Empfänger für zumindest eine vorbestimmte Proportion der Vielzahl von Übertragungen in einem vorbestimmten Zeitintervall auftreten.

5. Eindringdetektionssystem nach Anspruch 1, **dadurch gekennzeichnet, dass** die Überwachungseinrichtung einen gemeinsamen Prozessor (4) umfasst zum Vergleichen der potentiellen Alarmbedingungszustände für einen bestimmten Sensor mit entsprechenden potentiellen Alarmbedingungszuständen zumindest eines unmittelbar benachbarten Sensors und zum Feststellen eines stattgefundenen Eindringens, wenn der potentielle Alarmzustand für die bestimmte Station nicht mit dem Alarmsignal für den zumindest unmittelbar benachbarten Sensor übereinstimmt.

6. Eindringdetektionssystem nach Anspruch 5, **dadurch gekennzeichnet, dass** jeder Sensor (3A...3X) eine offene Übertragungsleitung umfasst, wobei ein erster Empfänger (3A) an den gemeinsamen Prozessor (4) angeschlossen ist, um Signale von den verschiedenen Empfängern zu verarbeiten, und die nachfolgenden Empfänger (3B...3X) zwei der offenen Übertragungsleitungen miteinander verbinden, wobei jeder Empfänger angeordnet ist, ein potentielles Eindringalarmsignal von weiteren Empfängern an den gemeinsamen Prozessor über jede dazwischenliegende offene Übertragungsleitung und jeden Empfänger zu übertragen.

7. Eindringdetektionssystem nach Anspruch 6, **dadurch gekennzeichnet, dass** der gemeinsame Prozessor (4) angeordnet ist, die Empfänger über die dazwischenliegenden Übertragungsleitungen mit Strom zu versorgen.

8. Eindringdetektionssystem nach Anspruch 1, **dadurch gekennzeichnet, dass** zumindest einer der Sensoren eine örtliche Antenne (58) umfasst.

9. Eindringdetektionssystem nach Anspruch 1, **dadurch gekennzeichnet, dass** die Empfänger in einer Vielzahl von Untersystemen (S1...SM) angeordnet sind, wobei jedes zumindest einen der Empfänger umfasst, und bei welchem die Überwachungseinrichtung einen gemeinsamen Prozessor (4) umfasst, wobei die Untersysteme physisch ge-

trennt voneinander sind, und dass die Untersysteme und der gemeinsame Prozessor jeweilige Sender-Empfänger aufweisen, um Alarmsignale von jedem Untersystem an den gemeinsamen Prozessor zu übertragen.

10. Eindringdetektionssystem nach Anspruch 1, **dadurch gekennzeichnet, dass** das vorbestimmte Frequenzspektrum zwischen etwa 88 MHz und 108 MHz liegt.

Revendications

1. Un système de détection d'intrusion **caractérisé par** une pluralité de capteurs (2A...2X) couplé à une pluralité correspondante de récepteurs (3A...3X), chaque récepteur présentant des moyens (11-24) pour recevoir, à partir du capteur qui y est couplé, un signal à fréquence radio présentant une multiplicité de transmission à des fréquences différentes dans un spectre de fréquence prédéterminé, le récepteur étant agencé pour détecter ladite multiplicité de transmissions et présentant des moyens de calcul (24) pour déterminer périodiquement, pour chacune de ladite multiplicité de transmissions, une mesure d'amplitude du signal correspondant, pour comparer chaque mesure d'amplitude de signal pour chacune des fréquences différentes avec au moins une valeur de seuil préfixée et, si l'amplitude dépasse la valeur de seuil pendant une période de temps prédéterminée, pour indiquer une condition d'alarme potentielle, le système comprenant en outre des moyens (4) pour surveiller les récepteurs pour la présence des conditions d'alarme potentielle, et pour signaler une condition réelle d'alarme dans le cas où au moins un des récepteurs indique des conditions d'alarme potentielle pour un nombre prédéterminé de différentes fréquences de transmission pendant la même période de temps.

2. Un système de détection d'intrusion selon la revendication 1, **caractérisé en ce que** chaque récepteur comprend des moyens (17, 18, 19) pour balayer un spectre radio FM et pour sélectionner un nombre desdites fréquences de transmission, et les moyens de calcul (24) sont agencés pour échantillonner l'amplitude du signal radio FM reçu à partir du capteur associé pendant un intervalle de temps prédéterminé, chaque échantillon constituant ladite mesure d'amplitude de signal, pour obtenir des statistiques pour une pluralité desdits échantillons sur chacune des périodes de temps successives, et pour régler périodiquement la valeur de seuil préfixée en fonction desdites statistiques.

3. Un système de détection d'intrusion selon la revendication 2, **caractérisé en ce que** les moyens de calcul (24) sont agencés pour comparer chaque mesure d'amplitude du signal avec une valeur de seuil supérieure préfixée et une valeur de seuil inférieure préfixée, pour déterminer des valeurs de variance supérieure et inférieure pour la pluralité d'échantillons d'amplitude, pour mettre à jour les seuils supérieur et inférieur en fonction de la variance supérieure et inférieure respectivement, et pour indiquer ladite condition d'alarme potentielle dans le cas où un nombre prédéterminé desdits échantillons d'amplitude se trouve en dehors d'une plage définie par les seuils supérieur et inférieure.

4. Un système de détection d'intrusion selon la revendication 1, **caractérisé en ce que** les moyens de surveillance (4) comprennent une unité processeur présentant des moyens pour recevoir des données concernant lesdites conditions d'alarme potentielle à partir desdits récepteur (3A...3X), les récepteurs présentant chacun des moyens (24,25,26) pour transmettre lesdites données à l'unité processeur (4), l'unité processeur étant agencée pour signaler ladite condition d'alarme réelle lorsque des conditions d'alarme potentielle signalées par un récepteur particulier se présente pour au moins une proportion prédéterminée de ladite multiplicité de transmissions pendant un intervalle de temps prédéterminé.

5. Un système de détection d'intrusion selon la revendication 1, **caractérisé en ce que** les moyens de surveillance (4) comprennent un processeur commun (4) pour comparer des états de conditions d'alarme potentielle pour un capteur particulier avec des états de conditions d'alarme potentielle d'au moins un capteur immédiatement avoisinant, et pour déterminer l'existence d'une intrusion dans le cas où la condition d'alarme potentielle pour ladite station particulière ne coïncide pas avec un signal d'alarme pour ledit au moins un capteur immédiatement avoisinant.

6. Un système de détection d'intrusion selon la revendication 5, **caractérisé en ce** chaque capteur (3A...3X) comprend une ligne de transmission ouverte, un premier récepteur (3A) étant connecté au processeur commun (4) pour traiter des signaux originaires des différents récepteurs, chacun des récepteurs ultérieurs (3B...3X) réalisant l'interconnexion de deux des lignes de transmission ouvertes, chaque récepteur étant agencé pour relier des signaux d'alarme d'intrusion potentielle à partir des récepteurs ultérieurs vers le processeur commun au moyen de l'une quelconque des lignes de transmission ouvertes et récepteurs intervenants.

7. Un système de détection d'intrusion selon la revendication 6, **caractérisé en ce que** le processeur commun (4) est agencé pour alimenter en énergie les récepteurs au moyen de la ligne de transmission intervenante.

8. Un système de détection d'intrusion selon la revendication 1, **caractérisé en ce que** au moins un des capteurs comprend une antenne localisée (58),

9. Un système de détection d'intrusion selon la revendication 1, **caractérisé en ce que** les récepteurs sont agencés selon une pluralité de sous-systèmes (S1...SM) comprenant chacun au moins un des récepteurs, et dans lequel les moyens de surveillance comprennent un processeur commun (4), les sous-systèmes étant séparés physiquement l'un de l'autre, les sous-systèmes et le processeur commun présentant des émetteurs-récepteurs respectifs pour communiquer des signaux d'alarme à partir de chaque sous-système vers le processeur commun.

10. Un système de détection d'intrusion selon la revendication 1, **caractérisé en ce que** ledit spectre de fréquence prédéterminé est d'environ 88 MHz. à 108 MHz.

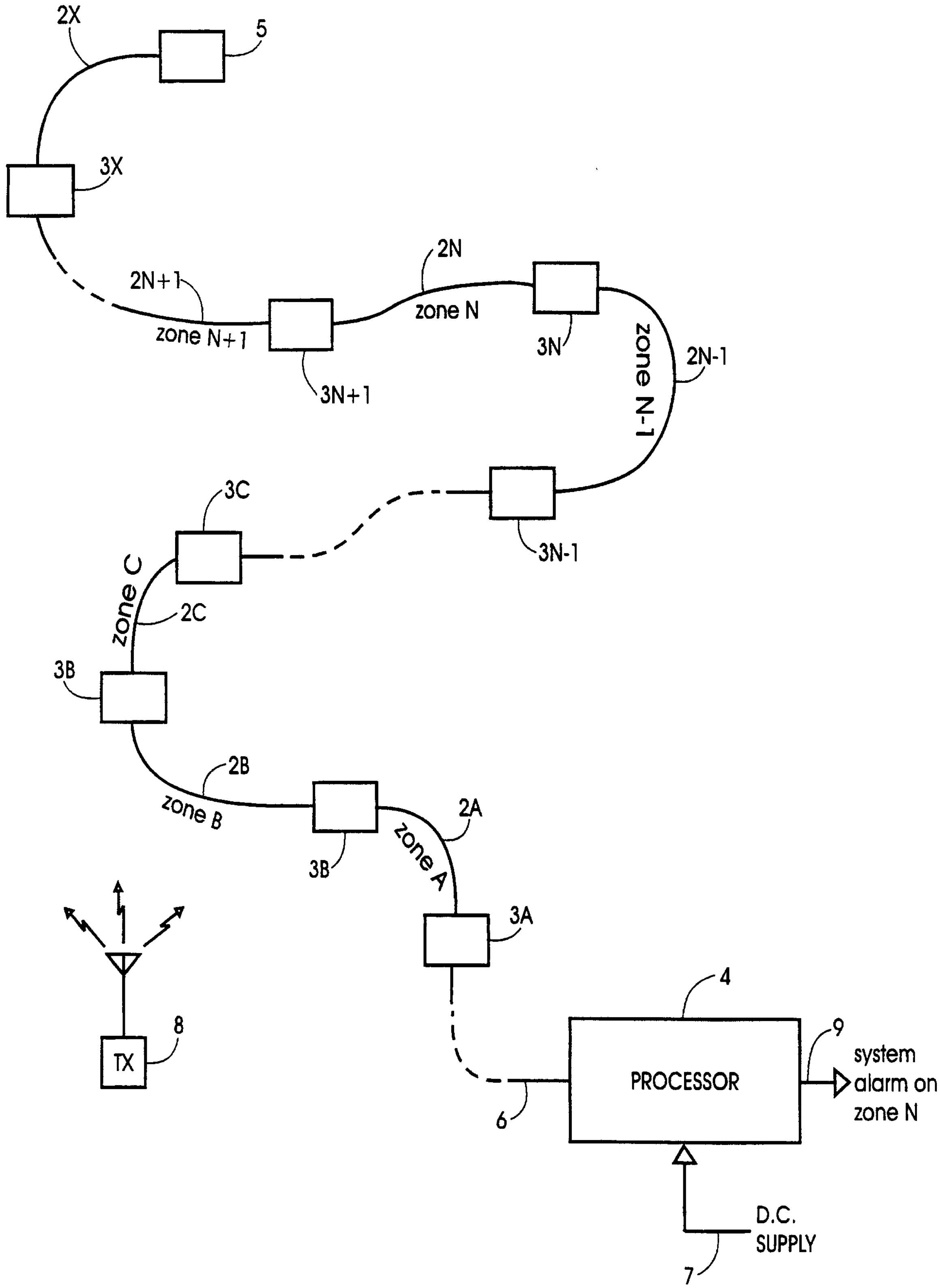

2X
5
3X
2N
2N+1
zone N+1
zone N
3N
3N+1
zone N-1
2N-1
3C
3N-1
zone C
2C
3B
2B
zone B
2A
3B
zone A
3A
4
8
TX
9
PROCESSOR
system
alarm on
zone N
6
D.C.
SUPPLY
7

FIG. 1

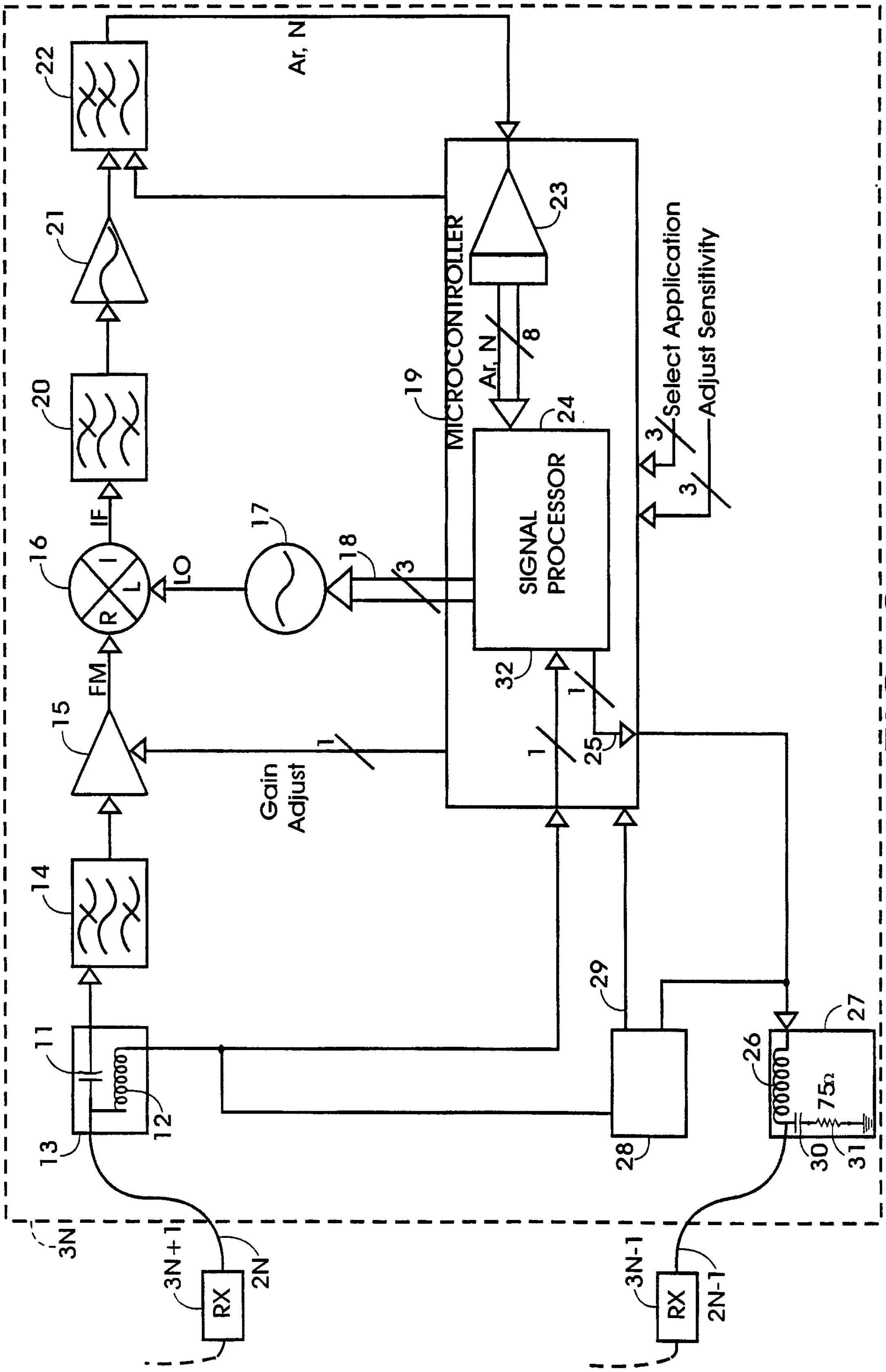

MICROCONTROLLER
SIGNAL PROCESSOR
Select Application
Adjust Sensitivity
Gain Adjust
Ar, N
FM
IF
LO
R
I
L
RX
RX
75Ω
3N
3N+1
2N
3N-1
2N-1

FIG. 2

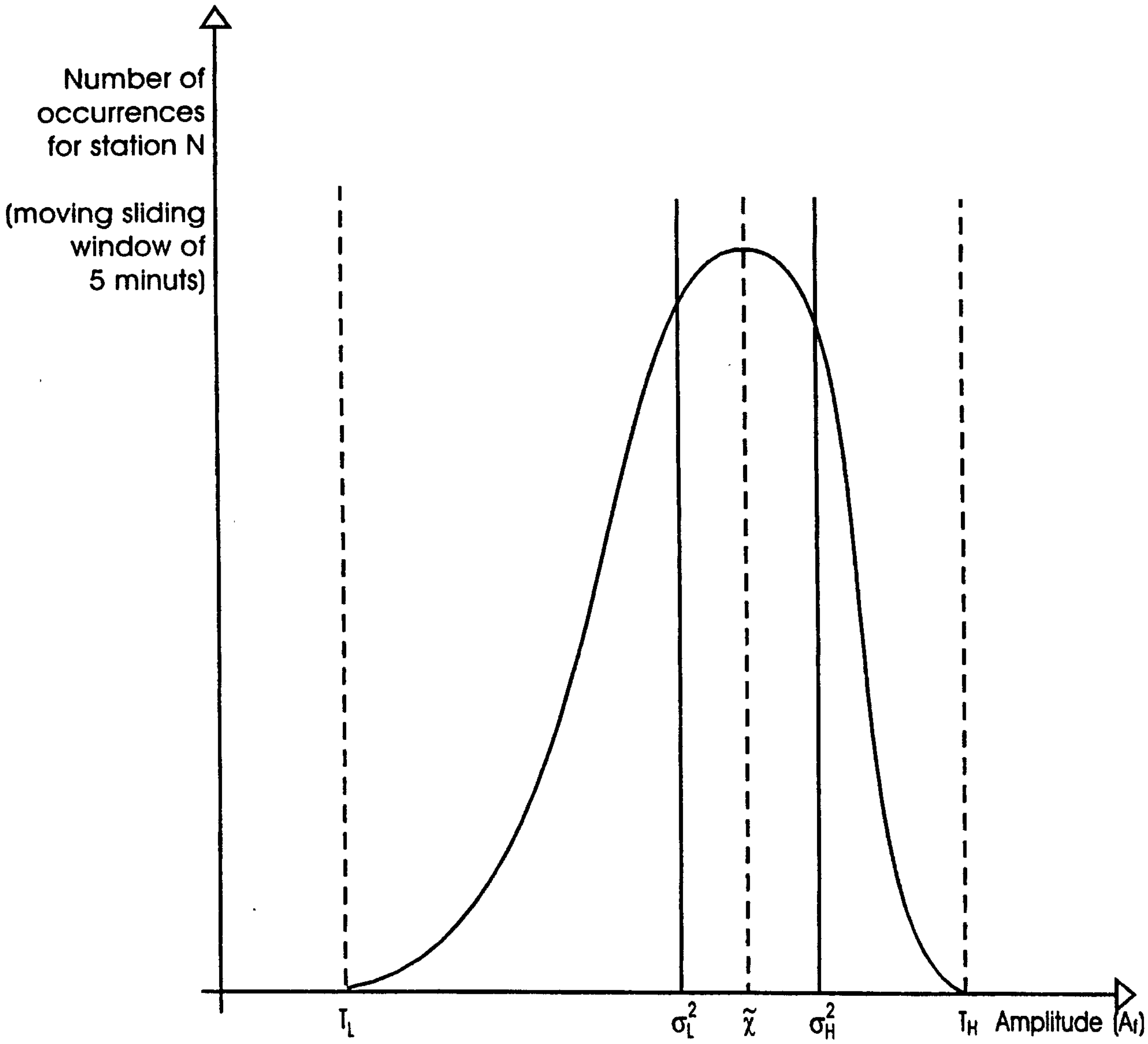

Number of occurrences for station N
(moving sliding window of 5 minuts)
T_L
σ_L^2
$\tilde{\chi}$
σ_H^2
T_H
Amplitude (A_f)

FIG. 3

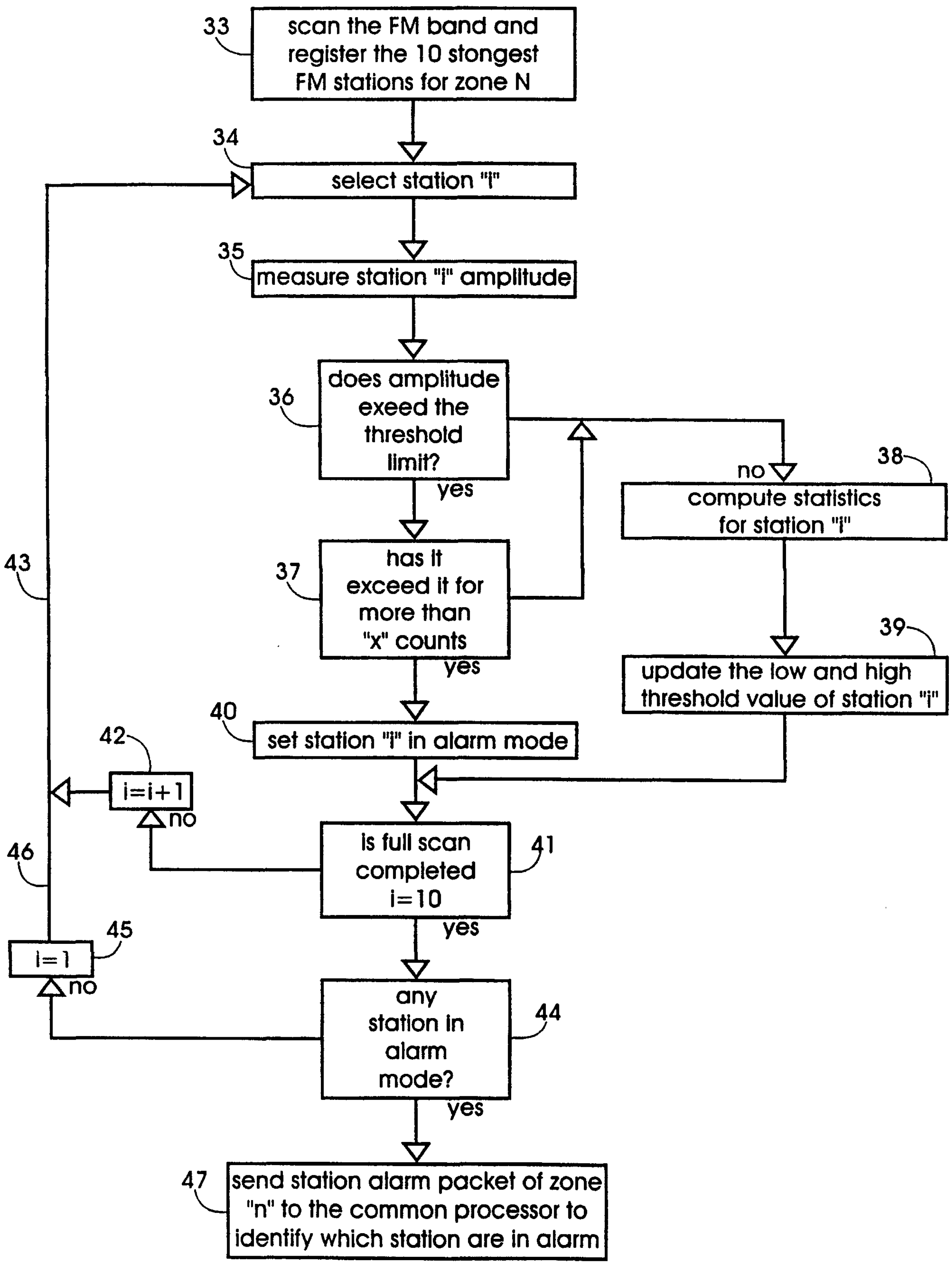

33
scan the FM band and register the 10 stongest FM stations for zone N
34
select station "i"
35
measure station "i" amplitude
36
does amplitude exeed the threshold limit?
no
yes
38
compute statistics for station "i"
37
has it exceed it for more than "x" counts
yes
39
update the low and high threshold value of station "i"
40
set station "i" in alarm mode
43
42
i=i+1
no
41
is full scan completed i=10
yes
46
45
i=1
no
44
any station in alarm mode?
yes
47
send station alarm packet of zone "n" to the common processor to identify which station are in alarm

FIG. 4

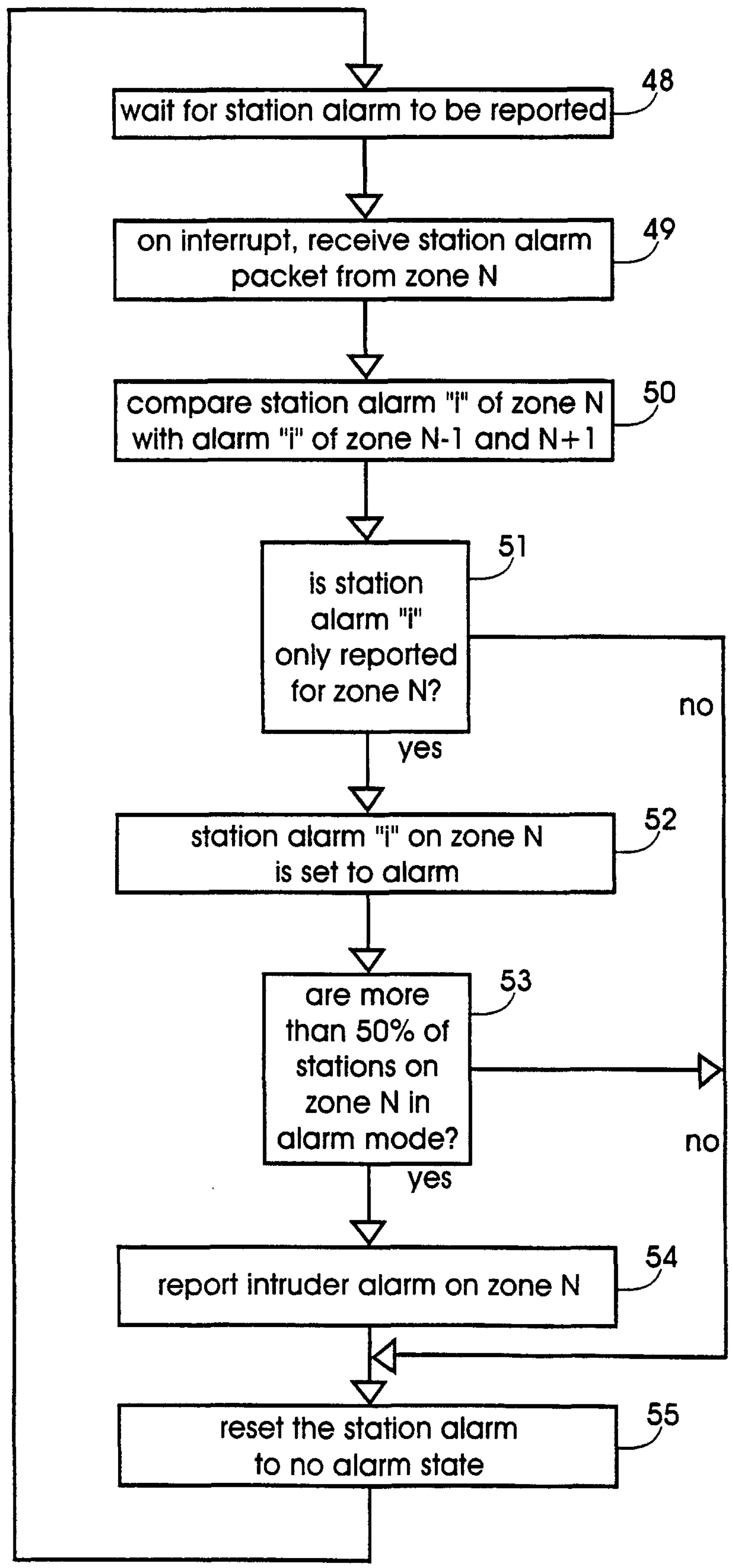

48
wait for station alarm to be reported
49
on interrupt, receive station alarm packet from zone N
50
compare station alarm "i" of zone N with alarm "i" of zone N-1 and N+1
51
is station alarm "i" only reported for zone N?
no
yes
52
station alarm "i" on zone N is set to alarm
53
are more than 50% of stations on zone N in alarm mode?
no
yes
54
report intruder alarm on zone N
55
reset the station alarm to no alarm state

FIG. 5

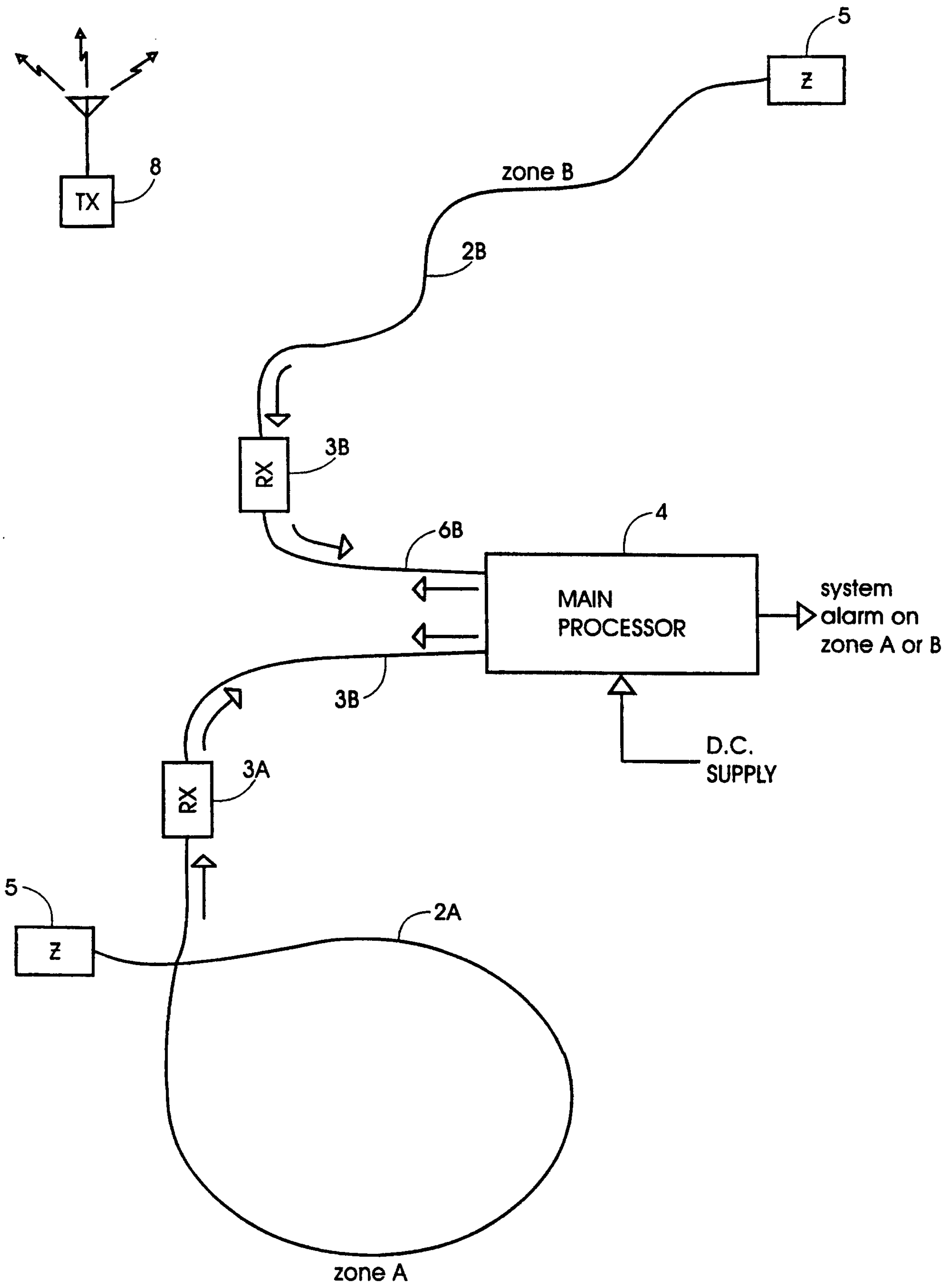

5
Z
TX
8
zone B
2B
RX
3B
4
6B
MAIN
PROCESSOR
system
alarm on
zone A or B
3B
D.C.
SUPPLY
RX
3A
5
Z
2A
zone A

FIG. 6

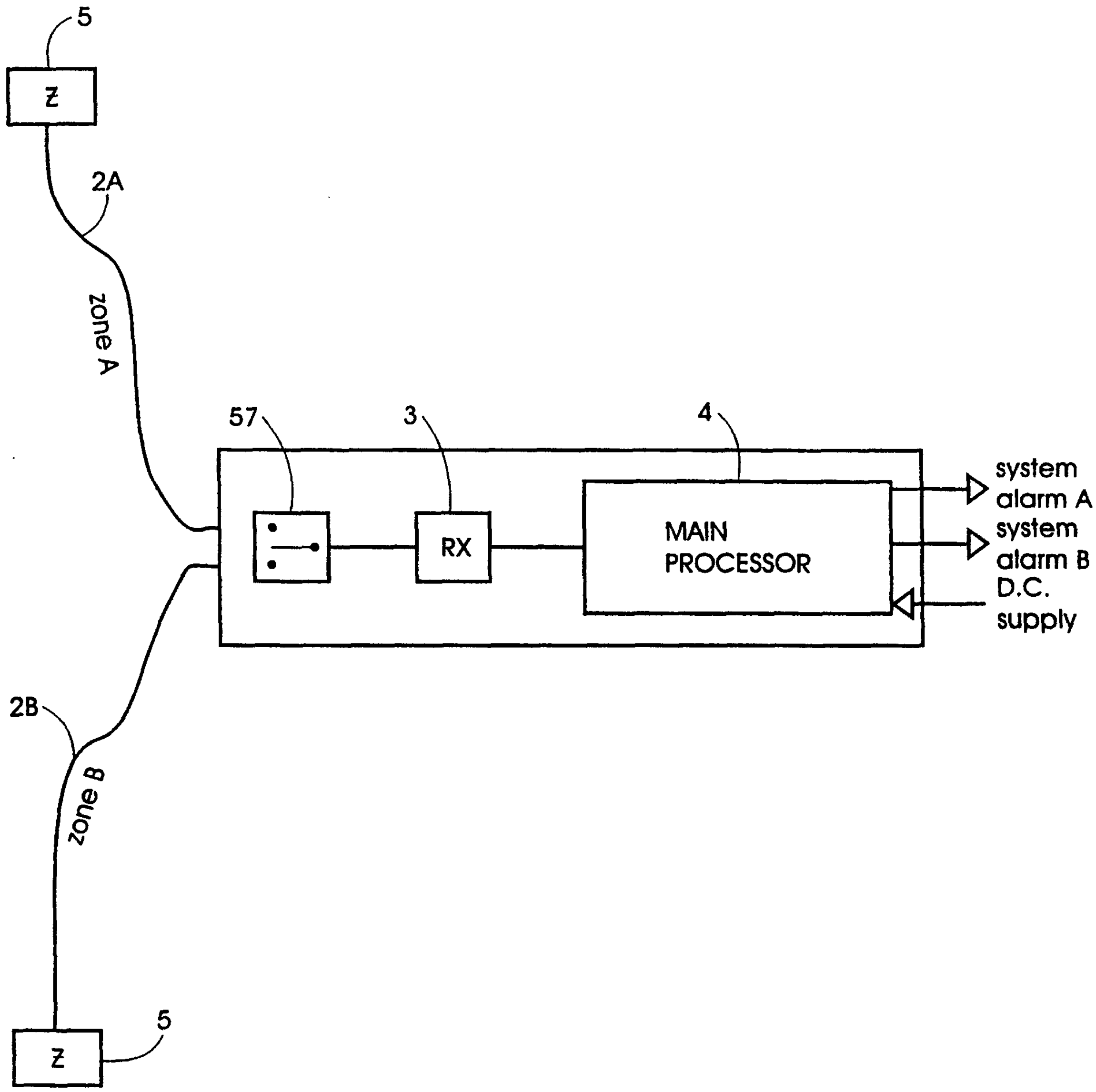

5
Z
2A
zone A
57
3
4
RX
MAIN
PROCESSOR
system
alarm A
system
alarm B
D.C.
supply
2B
zone B
Z
5

FIG. 7

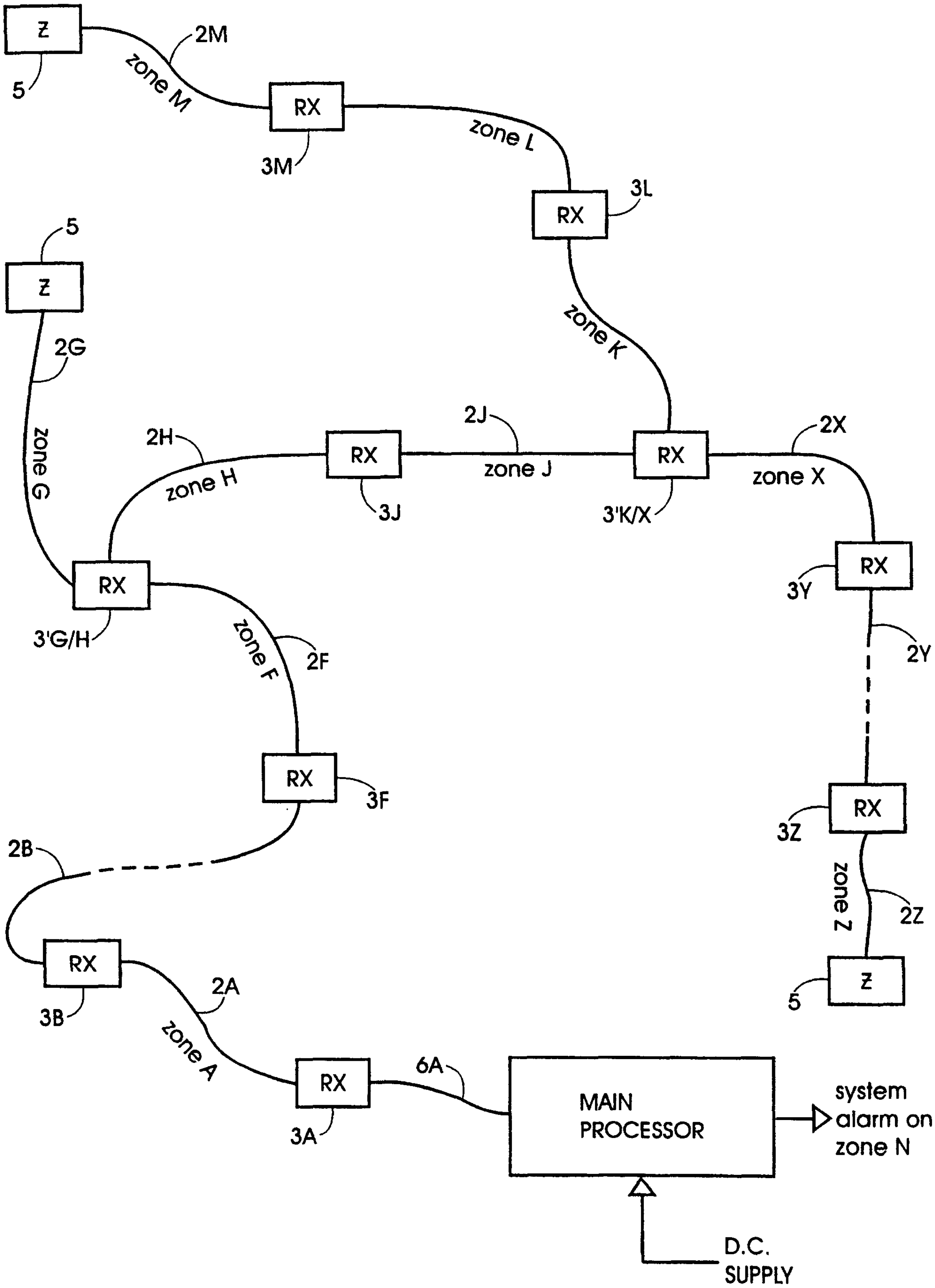
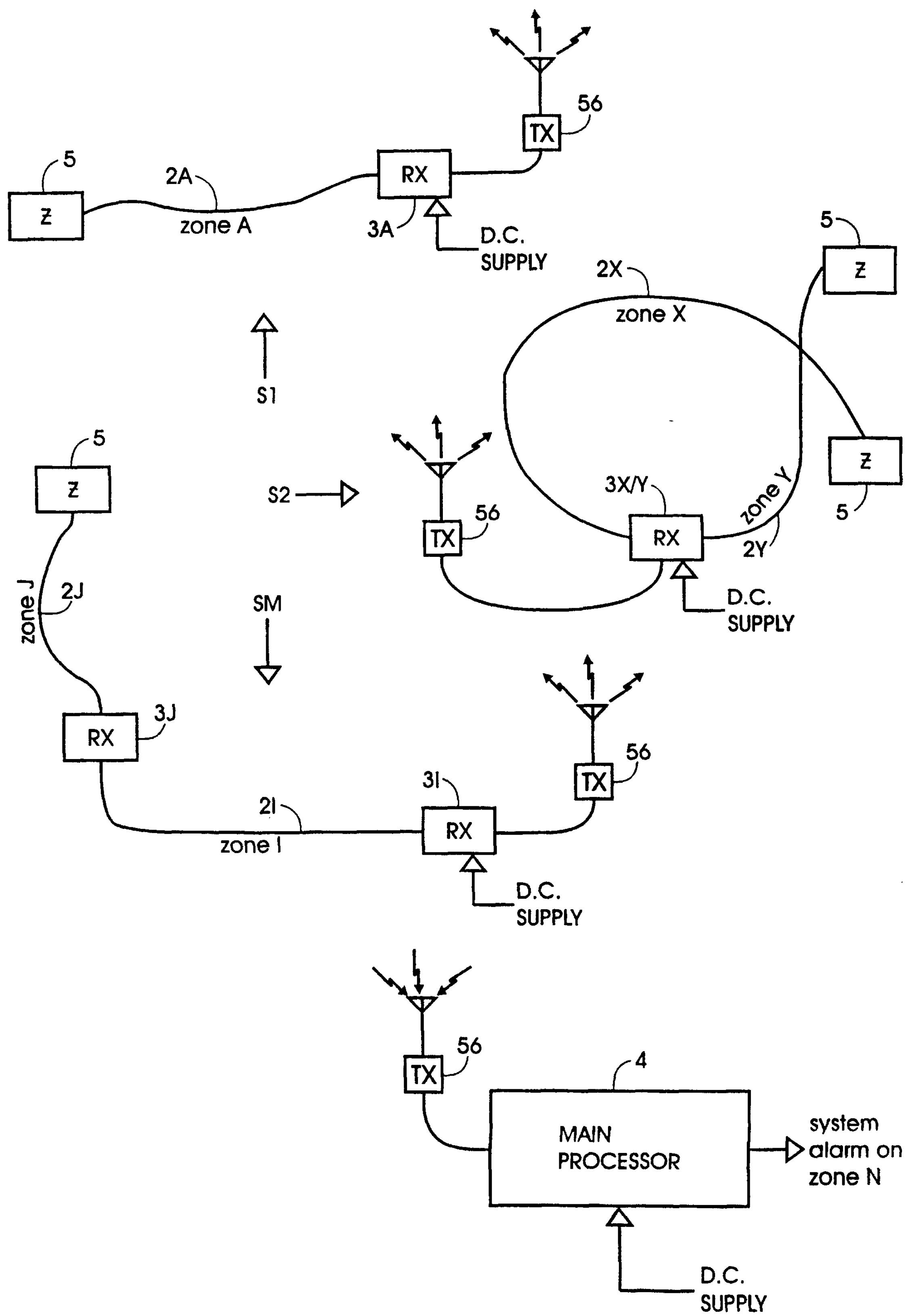

Z
5
2M
zone M
RX
3M
zone L
RX
3L
zone K
5
Z
2G
zone G
2H
zone H
RX
3J
2J
zone J
RX
3'K/X
2X
zone X
RX
3Y
2Y
RX
3'G/H
zone F
2F
RX
3F
2B
RX
3Z
zone Z
2Z
5
Z
RX
3B
2A
zone A
RX
3A
6A
MAIN
PROCESSOR
system
alarm on
zone N
D.C.
SUPPLY

FIG. 8



5
2A
zone A
RX
3A
TX
56
D.C.
SUPPLY
Z
5
2X
zone X
S1
S2
SM
Z
5
zone J
2J
3X/Y
RX
zone Y
2Y
TX
56
D.C.
SUPPLY
Z
5
RX
3J
3I
2I
zone I
RX
TX
56
D.C.
SUPPLY
TX
56
4
MAIN
PROCESSOR
system
alarm on
zone N
D.C.
SUPPLY

FIG. 9

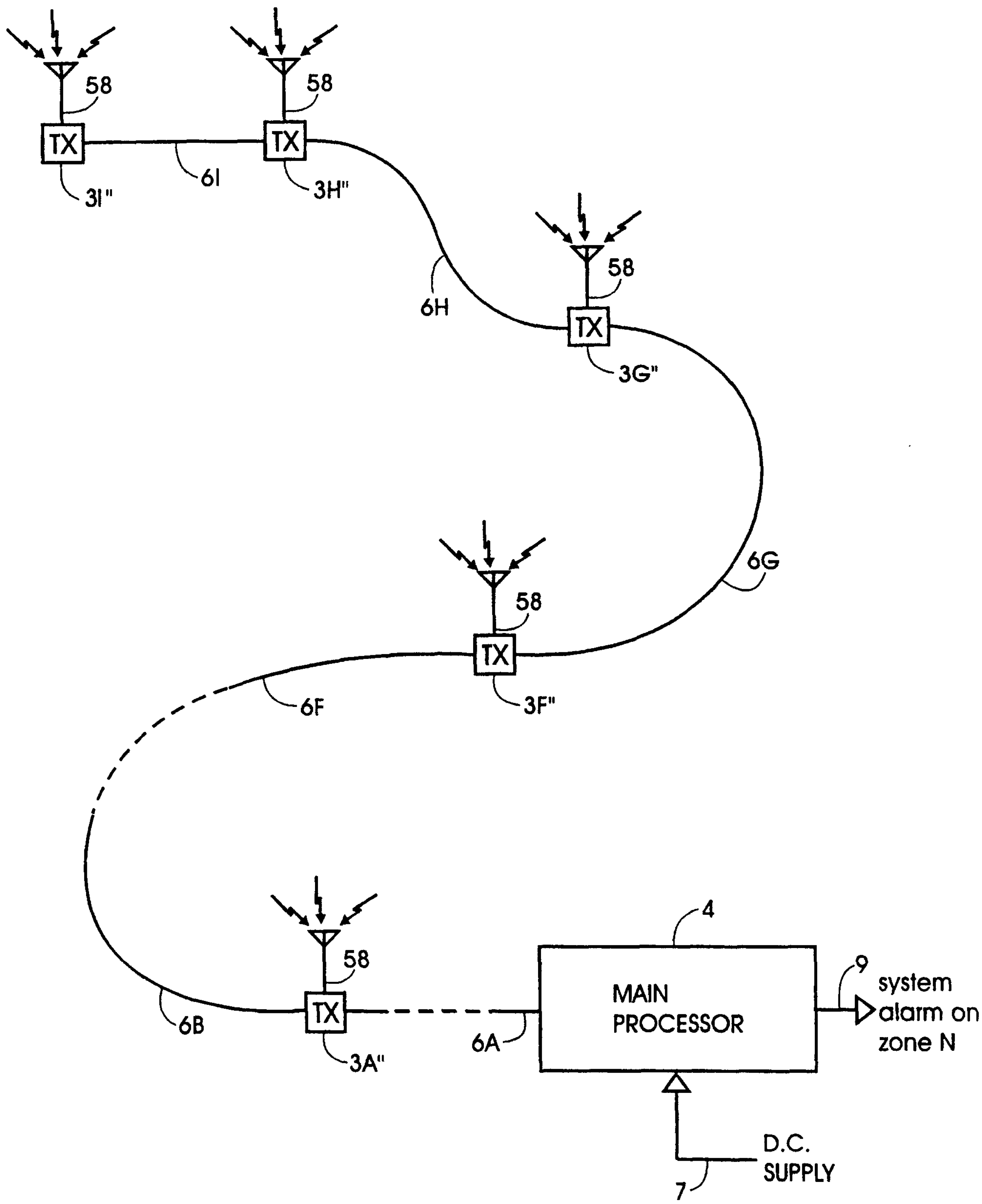

58
58
TX
TX
3I"
6I
3H"
6H
58
TX
3G"
6G
58
TX
3F"
6F
58
TX
6B
3A"
6A
4
MAIN
PROCESSOR
9
system
alarm on
zone N
D.C.
SUPPLY
7

FIG. 10

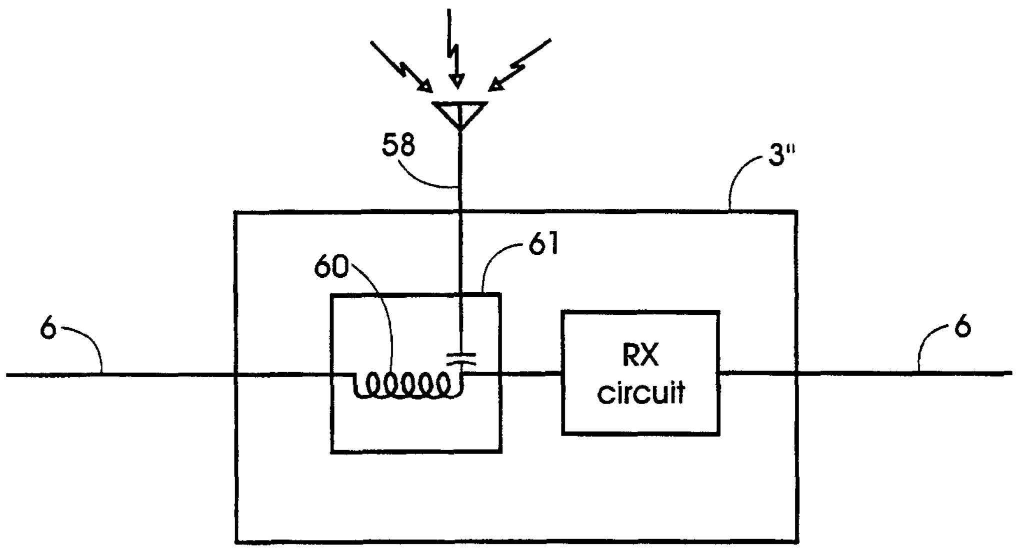
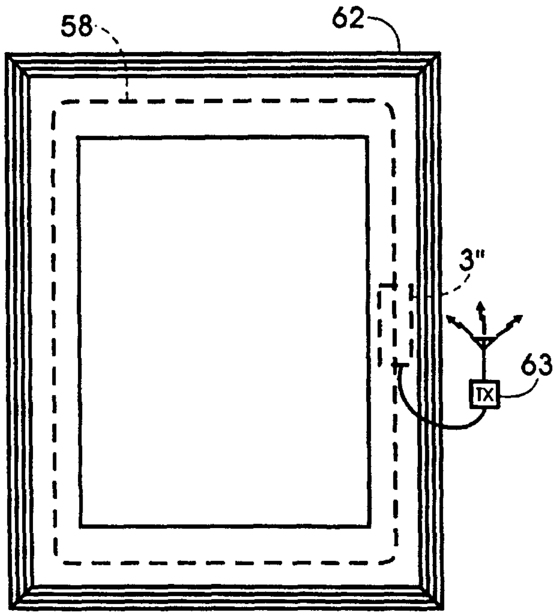


FIG. 11



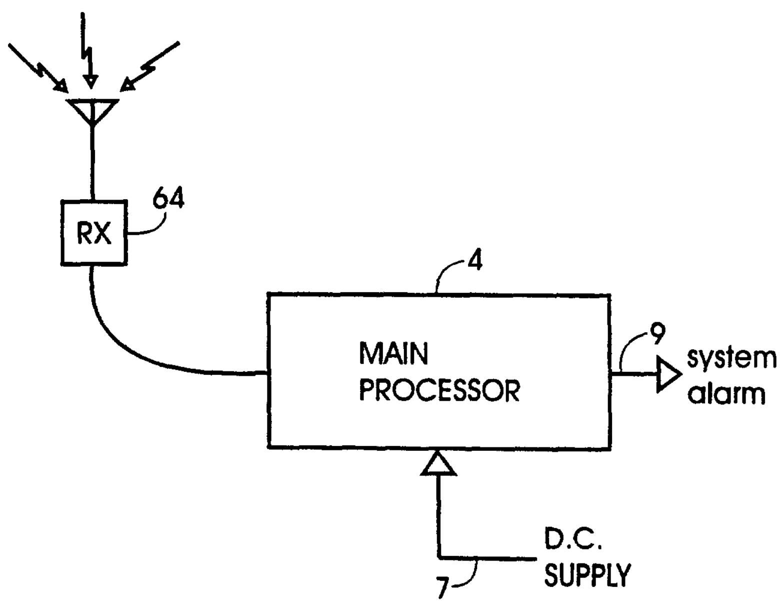


FIG. 12